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by

(10) Lee Preston/Gibson, Jr

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A Method to Determine Divisional Engineer Battalions' Training Measures of Effectiveness

by

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ABSTRACT

This thesis presents a methodology to determine the training measures of effectiveness for divisional engineer battalions. The evolution of the present Army training system and the divisional engineer battalion's structure are discussed. The representation of engineer critical tasks as networks and an analysis of the tasks' training measures of performance are developed. The analysis of the measures of effectiveness determined by the interaction of training and hardware measures of performance in a combat model provides the transition from training performance to combat effectiveness. The tasks network representation; the combat model and recommended changes and additions to the present training system are combined to form a proposed training management system.

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I. INTRODUCTION

In previous confrontations the United States Army has been able to withstand the first battles of a land war and rely on the mobilization of the nation's personnel and industrial strengths to eventually win the war. The next land war may be won in the first "come as you are" highly intense battles. Realizing this possibility, the U.S. Army has altered its objectives and methods of training. The training emphasis is now placed on the performance of critical combined arms tasks to specified training standards.

As a member of the combined arms team, the divisional engineer battalions play an important part in the first land battles. This thesis presents a methodology that should prove useful in providing a bridge between the divisional engineers' training performance and combined arms combat effectiveness.

Chapter II discusses the history of recent training developments and provides a description of the Army Training and Evaluation Program (ARTEP).

Chapter III lists the divisional engineer battalion's critical engineer tasks and develops a network representation of engineer tasks. The critical path method of time-cost trade-off analysis technique is used to provide a training analysis tool to the members of the engineer ARTEP system.

Chapter IV presents proposed changes and additions to the present engineer ARTEP system within the framework of a larger proposed Army training system. This training system uses the developments and techniques of Chapter III and the elements of the proposed Army training system to provide a transition from engineer critical task measures of performance to combined arms combat effectiveness.

The major conclusions presented in Chapter V state that the present Army training system should be changed. A feedback of training evaluation results should be required and the system should be augmented with elements to collect, store and analyze the feedback data.

II. DEVELOPMENT OF PRESENT ARMY TRAINING

Army training has undergone radical changes in both scope and procedures during the last five years. Although the alterations have occurred recently, the foundation for these changes was established almost twenty years ago.

The Army's focus of training has always been on the individual and collective levels, but until recently the training programs for each were disjoint sets.

A. PAST INDIVIDUAL TRAINING

Individual training equips a soldier to perform efficiently in his Military Occupational Specialty (MOS) and his grade. It also conveys to each soldier those skills and that knowledge he needs to advance in rank and responsibilities. In the past the individual level of training comprised at least 90% of the training at Army schools and less than 6% of the training in operational units [1]. The individual training system consisted of Basic Combat Training (BCT), Advanced Individual Training (AIT) (which were conducted at Army schools) and the annual MOS test administered in the units. Basic Combat Training acclimates the soldier to military life. He learns general military discipline, courtesy, physical conditioning and basic weapons' skills. In Advanced Individual Training the soldier is expected to gain knowledge of the basic skills of his MOS. This training will permit him

to perform his initial duties in his first operational unit assignment.

Once the soldier joins an operational unit his only formal individual training is taking the MOS test. The MOS test is a 125 multiple choice question written exam composed by the MOS proponent school. Its purpose is to evaluate the soldier's knowledge of all duty responsibilities based on the individual's MOS and grade. The score received is normative, relative to all others who take the exam. This test result and his enlisted efficiency report are critical in determining the soldier's eligibility for proficiency pay, qualification in primary and secondary MOS and promotions.

The past individual training concept concentrated the bulk of training in the Army schools when the soldier initially joined. After leaving the school, the soldier was motivated to learn on his own by taking individual knowledge tests which determined his advancement rate and potential.

B. PAST COLLECTIVE TRAINING

Until the early 1970's the Army's collective training was conducted in an annual training cycle mode. The system used was the Army Training Program (ATP). At the beginning of each training year, training objectives and training schedules were established at battalion and higher levels and executed through a top-down process beginning at the division level. The training began at the lowest echelon and sequentially proceeded to the next higher echelon. At each level

there were detailed instructions and lesson plans which included; what to teach, how to teach and how long to teach. After completion of all instructions at a particular level, a test would be administered, usually by the next higher level. The tests used were obtained from the list of Army Training Tests (ATT) and for company level and higher were referred to as Operational Readiness Training Tests (ORTT). At the end of the training year, the cycle usually concluded with large multiple unit maneuvers.

Underlying the Army Training Program (ATP) was the general mobilization model. This model assumed that the time necessary to mobilize and train units would be available before commitment to any major confrontation. Therefore, any unit which had not completed its training cycle would have sufficient time to do so before being committed to combat.

C. SYSTEM ANALYSIS IN TRAINING

In the early 1960's the U.S. Army began researching new approaches to training. Some of the research explored what civilian educators referred to as the systems engineering approach. This approach involved dividing the system into its component parts and examining each in complete detail; the purpose being to develop knowledge about the components, their interrelationships and dependencies. Through this analysis the overall system would be completely defined and each component would be described in terms of the system's requirements. The Human Resources Research Office of the

George Washington University (HUMRRO), while under contract with the U.S. Army, proposed a seven-step process for the development of a training program. This proposal dealt with training programs from the systems point of view. The development of the program began with a system analysis which identified "what the functions of the operating system are, how they are performed, and how the functional elements are related to one another" [2]. The next step was to develop a job model. This analysis was done from a human factors' point of view. The objective was to determine what the person performing the job was supposed to do, how he was to do it, with what other persons and machines he was to interact and how well he must perform all these functions for the system to continue to operate effectively. The third step in the analysis was to specify the required knowledge and skills necessary to accomplish the requirements in step two. The fourth step was to determine the training objectives that the individual must meet to insure satisfactory job performance. Step five was the construction of the training program. Development of a proficiency test was step six. This step was actually done in conjunction with the training program construction and was based on the job model in step two. The final step was the evaluation of the training program. This step was accomplished by evaluating the graduates of the program and performing a cost benefit analysis to determine the efficiency of the program.

This approach began to gain acceptance and in 1968 the Continental Army command (CONARC) published CONARC Regulation 350-100 Systems Engineering of Training (Course Design). This regulation proposed the following system design steps:

(1) Job Analysis

(2) Select Tasks for Training

(3) Training Analysis

(4) Develop Training Materials

(5) Develop Evaluation

(6) Conduct Training

(7) Quality Control

These steps taken together form a process very similar to that proposed by HUMRRO.

Researchers were also analyzing other aspects of Army Training. The ATP philosophy assumed a fixed curriculum and a fixed training time. The training programs were fixed in length and the evaluation of an individual was done on a normative scale in comparison to his classmates. As part of the systems analysis, researchers investigated varying the length of training relative to the time required to achieve the level of performance required. They proposed that the curriculum and the training time vary based on previous knowledge and capability, but that the course requirements be fixed at the level required to actually perform the tasks. This concept seemed to go hand-in-hand with the systems engineering approach.

D. SYSTEMS ANALYSIS IN INDIVIDUAL TRAINING

The training situation which was simmering in the late 1960's began to boil and late in 1971 the Chief of Staff of the Army directed the CONARC commander to consider ways of helping unit commanders conduct meaningful and challenging training. The Board for Dynamic Training was formed and conducted a survey of combat arms trainers in an attempt to identify training deficiencies and problems. The board discovered major problems with the training system being used at that time.

"First the Board found that one of the most significant problems in Army training involved the perception by combat arms soldiers that their opportunities for true professional development were limited" [3]. NCO's in units were resentful of the centralized system which administered tests annually to determine whether they should be promoted, retained or eliminated from the Army but did not offer substantial help in the MOS training required for the professional development. Specific complaints centered on the following areas:

1. Many study references were difficult to read and understand.
2. Reference publications were difficult to read and understand.
3. There was little professionally conducted MOS instruction in the units.
4. MOS tests were difficult to read and included questions on "nice to know" information.
5. The Noncommissioned Officer (NCO) schools had ample applications to fill all existing student vacancies for the next eight to ten year period.

Basically, the results of the survey showed that both the MOS and the NCO schooling system in use were totally unsatisfactory. The Board recommended the establishment of a training system as proposed in CONARC Regulations 350-100 for eight combat arms MOS'.

In 1974 the Interservice Training Review Organization led to the publication of TRADOC Pamphlet 350-30 which formally institutionalized the systems approach and performance oriented training in the U.S. Army Training and Doctrine Command (TRADOC).

The entire individual training system has undergone systems analysis. The training done at the Army schools is still primarily individual but the emphasis is on self-paced and performance-oriented training. For each MOS the proponent school has or is performing a complete system analysis and establishing a training system. In each MOS the critical tasks have been determined and completely defined in terms of standards and conditions. Materials and programs have been or are being developed to support unit training in these tasks to the required standards. Soldier's manuals have been compiled which cover in detail all requirements for every critical task of a particular MOS and skill level. Skill Qualification Tests (SQT) are being developed for each MOS and skill level.

The SQT's were designed within the systems structure to measure job performance and knowledge. "The goal is to provide an equitable, reliable and relevant means of

determining the job proficiency of enlisted soldiers" [4,p.1-1]. There are three possible levels of performance. The highest level is that of qualification. Achievement of this level implies the soldier meets the minimum requirements of the next higher skill level. This level of performance is required for promotion. The second possible performance level is that of a verification score, which implies that the individual is technically qualified at the present skill level. The third level is failure to verify which results in nonqualification at the present skill level.

The SQT is divided into three major parts: written component (WC), hands-on-component (HOC) and the performance certification component (PCC). The terms WC and HOC are self-explanatory. The PCC portion is used for tasks which it is not feasible to test but which are critical and therefore verified by the individual's military supervisor.

> Performance certification is the component where you should consider testing a task that (1) cannot be validly tested in the WC because of its skilled hands-on requirements, and (2) cannot be tested in the HOC because of administrative constraints. Cutting a roadbed with a bulldozer is a good example. To test this in the HOC would probably take several hours and a sizable expanse of terrain; moreover, equipment and field requirements could probably not be justified merely for testing purposes [4,p.6-3].

The HOC and the PCC are included in the SQT to insure the evaluation of the performance of tasks to specified standards. One of the requirements of any task to be tested is that it be in the applicable soldier's manual.

An integral part of the enlisted training system is the establishment of a viable NCO schooling system. The process is still evolving but its goal is to provide a sequential system of schools beginning at a basic level and culminating with the Sergeants Major Academy.

E. SYSTEMS ANALYSIS IN COLLECTIVE TRAINING

Training developments were also changing the collective training programs in the Army. The systems approach was beginning to be applied to the training programs of units in the operational force. An additional impetus to change was that the Army Training Program (ATP) was based on the mobilization model. In the early 1960's it became apparent to top Army leaders that in the future there was a high probability that confrontation would be intense "come as you are" battles of limited objectives, with the results of the first days determining the final outcome. Given that situation, the ATP cyclical training proficiency would not suffice. Units had to be kept at a high state of training and readiness throughout the training year and the training program must have this as its primary goal. The performance-oriented systems approach was an obvious candidate to replace the ATP as the collective training philosophy.

Due to the ATP's shortcomings, the commander of TRADOC initiated the ATP/ATT Revitalization Program. The Army Training and Evaluation Program (ARTEP), which eventually developed from this program, was officially approved by the Army in August, 1975.

The initial analysis identified the battlefield jobs of units from squad to battalion. Next these jobs were analyzed to determine the critical tasks at each echelon, which when performed to standard would enable that unit to satisfactorily accomplish its mission on the battlefield. The required standards and conditions of performance for each task provided the training objective. The materials developed to support the training were the ARTEP manuals for each unit in the Army. These manuals list all the critical tasks, their standards and conditions of performance. They also provide references for future study of specific tasks. Trainers at all levels can refer to the applicable ARTEP manual to determine their collective training objectives.

The ARTEP decentralized training control was given to the unit trainers with the stipulation that the performance oriented training be executed. The general concept of the training program is to provide the unit commanders with the applicable ARTEP manual and allow him to design a unit training program based on his unit's training status and the tasks, conditions and standards found in that ARTEP manual. The commander then manages the training until he decides he wants to evaluate the unit's progress or until he is to be evaluated by a higher commander. After the evaluation the unit commander reevaluates his unit's training program. This process is repeated on a continuous basis.

The evaluation step in the ARTEP is now being designed to be a process of validation of training and is to be

considered an integral part of the program to be used strictly as a diagnostic tool for the unit commander. All evaluations must use the same tasks, conditions and standards as those used in training and must be performance-oriented on a "go", "no-go" basis. If the unit meets the standards, a "go" is given and if not a "no-go" is given. It is the unit commander's analysis of the "go", "no-go" results and the evaluators comments that allow him to update his training program. Evaluations performed by a higher commander are used by him as validation of his subordinate unit's training status. Each commander is accountable for training two echelons below his own.

The evolution of ARTEP manuals is the responsibility of the proponent schools. The information system between the schools and the units in the field is informal. Comments and recommendations on the concepts of training, the tasks, the conditions or the standards are requested in the manuals themselves, but providing the information and feedback by units is optional.

The ARTEP is an attempt to meet the objective of maintaining units at a high training level, so as to be prepared to fight an intense "come as you are" war.

F. ARMY TRAINING CENTER

One of the primary directions of present collective training development is towards an Army Training Center. "The Army foresees one or more National Training Centers

large military reservations which can support the kind of combined arms training needed to ready the total Army for battle in Europe" [5]. The Army planners have proposed one Army Training Center to be located at Fort Erwin, California. The purpose of the NTC is to provide a location where Army units can perform essential training that cannot be done at home station because of physical limitations or prohibitive costs of providing a NTC type of environment at all home stations. The concept of operations is to rotate all active Army CONUS battalions and brigade headquarters through the center on the average of once every eighteen months. Two battalions at a time will draw equipment and then train at the center for fourteen days. Scenarios will include live fire and engagement exercises. The engagement exercises will use the Multiple Integrated Laser Engagement Simulation System (MILES) and the full complement of combined arms weapons, to include tactical air support. Extensive use of instrumentation is planned. All the key players will be linked into an instrumentation system that will record their location, communications and activities, to include firings.

The entire system is designed not only to assist the units being evaluated but to facilitate the gathering of quantitative data about simulated battlefield performance and effectiveness of organizations and systems. Testing is scheduled to begin in 1978. A limited number of battalions are scheduled to undergo training at the center in 1982.

G. TRAINING SUPPORT DEVELOPMENT

There have been recent advances in the area of training support. The systems presently being used are; Squad Combat Operation Exercise Simulation (SCOPES) and Real Training (REALTRAIN). SCOPES is a two-sided, free play squad exercise in which each player has a number on his helmet and a scope on his rifle. As the engagement proceeds, a player is considered "killed" when an opponent has sighted him, announced his number and the number is verified by a controller. The same concept of numbers and scopes is used in REALTRAIN but the engagement includes larger weapon systems. The major constraint on these techniques is the necessary overhead required for controllers and evaluators. Each weapon system must have its own evaluator to verify any actions. The manpower requirements become almost prohibitive.

Because of the problems described, research was directed towards automated combat simulations systems. The system farthest in development is the Multiple Integrated Laser Engagement System (MILES). Each weapon system has sensors affixed at critical locations and uses eye safe lasers to fire at opposing forces. When a weapon system's sensors are activated by a laser, a buzzer is sounded which can only be silenced by deactivating the weapon system. The weapon system will remain inactive until reset by a controller. "MILES is about one-fifth the price of the next cheapest hit/kill indicator or tactical movement simulator that we can find any place in the world ..." [6,p.29].

Another sector of training support under study is the revision of field manuals and technical manuals. The Integrated Technical Documentation and Training (ITDT) concept provides a packet of job performance aids and job training materials. These manuals are human engineered for the "real world" capabilities of today's troops and are designed to allow even novices to follow the instructions and perform required technical tasks. "ITDT is probably the most important single support concept that we have to improve training in the Army today" [6,p.30].

H. OVERALL TRAINING SYSTEM

In addition to assessing individual and collective systems separately, the Army training community has begun to look at the overall system which connects the two subsystems. Besides the natural progression from individual tasks to collective tasks, this analysis is motivated by the realization that in the future the bulk of individual training will also be at the unit level. Due to the quantum jumps of technology in the Army and prohibitive costs of Army schooling, the required increase in individual training will necessarily be focused at the unit level. To assist the unit commander in the area of individual training, the proponent schools are providing a commander's manual which lists the individual training requirements of personnel in his unit. Also, the results of SQT's are reported to the unit commander to give a "status report"

on each individual's training performance. Training Circular 21-5-7 (Training Management in Battalions) is an attempt to provide unit commanders with a method of organizing training through the use of soldier's manuals and ARTEP manuals. This approach enables his soldiers to be validated for advancement and his unit to perform to standard.

The development of an overall training system is in the initial stages. There will undoubtedly be changes in both the individual and collective training systems. These changes will be necessary to insure compatibility and completeness in relation to the overall system.

I. ARMY TRAINING CHALLENGES

The Army has gone from a stagnant and disjoint training system to a dynamic more compatible system. Changes are being proposed frequently in almost all areas of training. The control and direction of these changes appears to be the greatest challenge on the horizon. Army leaders must develop measures of effectiveness to apply to these changes to determine their effectiveness-cost ratio. Given the existing cost and budget constraints not all proposed changes can be implemented. Future success in battle is dependent on the choices made.

The focus of this thesis is on the engineer collective training system. Chapter three provides a description of critical engineer tasks and presents techniques for representing and analyzing these tasks.

III. CRITICAL ENGINEER TASKS AND ANALYSIS

"The Army's primary objective is to win the land battle ..." [7]. This statement precisely describes the Army's training objective – train to be able to win the land battle.

In central Europe, the first battle will begin in the covering forces area. If the Army is to have any chance of achieving its primary objective in the "come as you are" intense battle situation, divisional units must have had the training necessary to win that first battle. To win it will take combined arms teamwork. Engineer units are an integral member of that team. "As movement and lethality on the battlefield increase, the requirement to reinforce the terrain increases" [8,p.i]. The engineers provide to the combined arms team the terrain orientation that can be used as a combat multiplier or equalizer. Failure to use the terrain can prove fatal. Thus, it is crucial that the divisional engineers and other engineer units within the division's area of operations train to be able to accomplish their portion of the combined arms objective.

A list of tasks for the divisional engineer battalion is presented in this chapter. These tasks are the divisional engineer battalion's critical ARTEP tasks – those tasks which the battalion must be able to do to accomplish its portion of the combined arms objective. To assist engineer

ARTEP developers, trainers and evaluators, techniques of representing and analysing engineer critical tasks and missions are presented. The techniques developed will also be used in a proposed training system to be developed in Chapter IV.

A. DIVISIONAL ENGINEER BATTALION

Before addressing the critical tasks of the divisional engineer battalion, a description of the divisional engineer support system is presented. The focal point of engineer support in the division's area of operations is the divisional engineer battalion. This battalion is organic to the division and includes a headquarters company, four combat engineer companies and a bridge company. The headquarters company is composed primarily of the battalion and company staff but also contains an equipment platoon which has construction equipment. The other equipment in the company are two armored personnel carriers, maintenance trucks and many administrative and supply support vehicles. Each of the four combat engineer companies has three platoons and each platoon has three squads. The primary squad vehicle is the armored personnel carrier which is identical to those used by infantry squads. Each squad has one demolition set, one pioneer tool set and mine detectors. Each platoon headquarters has a larger demolition set and larger pioneer set. The platoon also has one bucket loader and one dump truck. At the headquarters of the four combat companies there are two

combat engineer vehicles (CEV), a bulldozer, a dump truck, an armored personnel carrier that contains the company headquarter's communication equipment, and at least one armored vehicle launched bridge attached from the bridge company. The combat engineer vehicle (CEV) is a M60A1 tank chassis and turret with a 165mm demolition gun. It is primarily used against "hard" fortified positions such as, concrete bunkers. The armored vehicle launched bridge (AVLB) is a M60A1 Chassis with a hydraulically launched "scissors" bridge superstructure which can span gaps up to 60 feet. In addition to the AVLB the bridge company has the division's only rafting and bridging assets. The light tactical raft system (LTR) can be used to ferry light to medium weight vehicles across water obstacles. The mobile assault bridge system (MAB) is used to bridge rivers or to provide heavy vehicle (tank) rafting.

The divisional engineer battalion commander is the division engineer and is a member of the division commander's special staff. He is responsible for the coordination of all engineer operations in the division area of operations, to include any additional corps engineer units attached to the division. Typically each of the combat companies is in direct support of one of the divisions's three brigades. The fourth combat company, the bridge company, the headquarters company and augmenting corps engineers remain in general support of the division to be assigned to tasks as needed. The commander of the combat engineer company in

direct support of a brigade is that brigade's engineer and distributes engineer resources. Normal allocation is one engineer platoon to each battalion task force and one squad to each company team. Thus, each level of the forward combat maneuver force within a division has its own direct support engineer element.

In addition to the engineer support provided to the brigades, the division engineer coordinates the general engineering tasks required in the brigade and division rear areas. This general support is accomplished by the remaining divisional engineer units and the attached corps engineer units. The corps engineer units are basically organized like the divisional engineer units, except that their equipment is construction oriented. There are many engineer units operating in the division area with many diverse missions. This thesis focuses on the divisional engineer battalion of an armored or mechanized infantry division.

B. DIVISIONAL ENGINEER FUNCTIONAL AREAS, MISSIONS AND CRITICAL TASKS

There are four basic functions of the engineers in the divisional area. The four functions will be discussed along with their missions and critical tasks. Each function can be divided into its component missions and each mission can be partitioned into smaller missions or critical tasks.

Mobility, countermobility, survivability and general engineering are the functional areas of major engineer contribution to the combined arms team. Mobility is "oriented

on reducing or negating the effects of natural or man made obstacles, to improve movement of maneuver fire units and movement of critical supplies" [8,p.2-2]. The maneuver elements must be able to move around the battlefield to provide maximum influence on battle results. They need to move on expedient routes that provide cover and concealment. Engineers must improve existing paths or quickly provide satisfactory temporary routes. An engineer goal is to provide continuous mobility. "Countermobility is obstacle construction" [8,p.2-4]. While insuring that friendly forces have continuous mobility, engineers should reduce the enemy's mobility and effectiveness by constructing obstacles. These obstacles should increase enemy casualties by increasing friendly weapons effectiveness through lengthening the time available to acquire and engage the enemy. Increasing the maneuver units' survivability also increases their combat effectiveness. Prepared defilade positions enable friendly weapon systems to decrease their probability of being detected and hit, while increasing those of the enemy. Some general engineering tasks must be accomplished, even in the most forward elements. The establishing of water points and the collection of engineer intelligence must be a continual process accomplished by the divisional engineer battalion.

The component missions and critical tasks lists of the four functional areas are listed in Tables I through IV.

TABLE I

FUNCTION(1) - COUNTERMOBILITY

MISSION(1,1)	-	Obstacle Developments
TASK(1,1,1)	-	Install point minefield
TASK(1,1,2)	-	Install protective minefield
TASK(1,1,3)	-	Install tactical minefield
TASK(1,1,4)	-	Install phony minefield
TASK(1,1,5)	-	Install interdictive minefield
TASK(1,1,6)	-	Disable bridge
TASK(1,1,7)	-	Construct riverline obstacle
TASK(1,1,8)	-	Crater roads
TASK(1,1,9)	-	Construct tank ditch
TASK(1,1,10)	-	Construct non-explosive anti-vehicular obstacles
TASK(1,1,11)	-	Construct barbedwire entanglements
TASK(1,1,12)	-	Construct booby traps

TABLE II

FUNCTION(2) - SURVIVABILITY

MISSION(2,1)	-	Field fortifications
TASK(2,1,1)	-	Construct primary fighting positions
TASK(2,1,2)	-	Construct alternative fighting positions
TASK(2,1,3)	-	Construct supplemental fighting positions
TASK(2,1,4)	-	Cut and provide timbers
TASK(2,1,5)	-	Construct personnel trenches
TASK(2,1,6)	-	Construct vehicular trenches
TASK(2,1,7)	-	Construct decoy positions
TASK(2,1,8)	-	Construct command and control facilities
TASK(2,1,9)	-	Construct protective ditches

TABLE III

FUNCTION(3) - MOBILITY

MISSION(3,1)	-	Route reconnaissance
TASK(3,1,1)	-	Maintain combat roads
TASK(3,1,2)	-	Construct combat trails
MISSION(3,2)	-	Gap crossing
TASK(3,2,1)	-	Bridge dry gap
TASK(3,2,2)	-	Reduce dry gap banks
TASK(3,2,3)	-	Construct aluminum footbridge
TASK(3,2,4)	-	Construct and operate rafts
TASK(3,2,5)	-	Construct a bridge
TASK(3,2,6)	-	Construct temporary ford sites
TASK(3,2,7)	-	Prepare swim sites
TASK(3,2,8)	-	Operate assault boats
TASK(3,2,9)	-	Inspect and repair captured bridges
TASK(3,2,10)	-	Reinforce bridge
TASK(3,2,11)	-	Classify bridge
MISSION(3,3)	-	Obstacle reduction
TASK(3,3,1)	-	Assault minefield breach
TASK(3,3,2)	-	Conduct deliberate minefield breach
TASK(3,3,3)	-	Clear a minefield
TASK(3,3,4)	-	Conduct route clearance operations
TASK(3,3,5)	-	Breach a nonexploding obstacle
TASK(3,3,6)	-	Clear rubble and blocking vehicles
TASK(3,3,7)	-	Construct intrabuilding passages
TASK(3,3,8)	-	Modify structures for weapon firing

TABLE IV

FUNCTION(4) – GENERAL ENGINEERING

MISSION(4,1)	–	Engineer intelligence
TASK(4,1,1)	-	Perform obstacle reconnaissance
TASK(4,1,2)	-	Conduct hasty route reconnaissance
TASK(4,1,3)	-	Conduct bridge reconnaissance
TASK(4,1,4)	-	Conduct river reconnaissance
TASK(4,1,5)	-	Conduct enemy minefield reconnaissance
TASK(4,1,6)	-	Conduct material or equipment reconnaissance
MISSION(4,2)	-	Water supply
TASK(4,2,1)	-	Operate water point

These tasks were chosen from Combat Engineering Tasks (Manpower and Equipment Estimates), Engineer Family of Systems Study (E-FOSS), April 1978 [9]. This study effort was developed by the U.S. Army Engineer Studies Group to be used as the data base for the TRADOC E-FOSS Workshop. The workshop was an initial step in an extensive analysis of the combat engineer system conducted by the U.S. Army Engineer School. The tasks chosen from this data base were those applicable to the divisional engineer battalion and compatible with ARTEP 5-145 [10], the applicable ARTEP manual. The arbitrary coding used is an attempt to facilitate component mission and task identification. For example, Task(2,1,6) is the 6^{th} task (construct vehicular trenches) of the 1^{st} mission (field fortifications), from the 2^{nd} functional area (survivability).

The personnel, time and equipment estimates used in this thesis are taken from this data base. These estimates were obtained by the study team from ARTEP standards or the applicable field manuals.

C. CRITICAL TASKS AND MISSIONS NETWORKS

The technique proposed here is to represent a critical task as a system of subtasks and a mission as a larger system of selected critical tasks. This technique is used to analyze the effect of personnel and equipment methods on the time required to complete a critical task or mission.

Any of the critical tasks may be partitioned into component subtasks. The subtasks are distinct jobs that must be executed in a specific sequence. Some subtasks may be accomplished in more than one way. The number of ways is constrained only by the number of possible combinations of personnel and equipment. In essence, each critical task is a system of subtasks arranged in a specific sequence with multiple methods of execution.

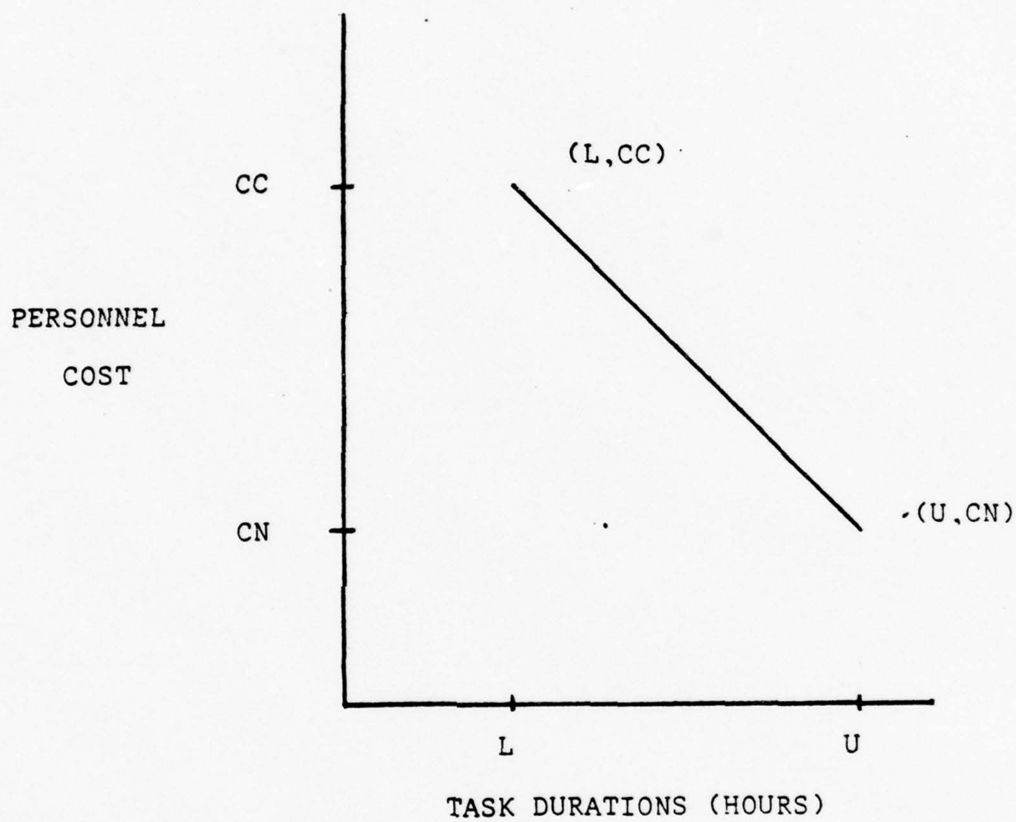
Network theory provides a technique that can graphically represent a sequence of subtasks. It can also show the effects of different combinations of personnel and equipment on the time required to complete each subtask and the time required to complete the entire sequence of subtasks. A task time-personnel trade-off analysis can be done for each feasible equipment method. The analysis begins by determining the different possible methods to accomplish the subtasks. For each possible method, estimates for the minimal number of personnel to complete each subtask in a maximum acceptable time are determined. These parameters are designated as the normal cost (CN) and the normal time (U) for each method of execution of each subtask. Next, for each method an estimate for the minimal subtask completion time is determined, based on an estimate of the maximum feasible number of personnel to accomplish the subtask. These parameters are defined to be the crash time (L) and the crash cost (CC) for each method of execution of each subtask. These calculations

determine points on the subtask personnel trade-off graph and the values of the variables shown on the subtask arc representation. Figures 1 and 2 are examples of a time-personnel trade-off graph and an arc representation of a subtask given a particular method of execution.

Figure 1 shows the line between points (L,CC) and (U,CN) as a straight line. One of the assumptions of the network technique being presented is that the time-personnel trade-off for each method of executed of each subtask can be adequately estimated by a linear or piecewise-linear curve. The parameter, actual cost (CA), in Figure 2 represents the personnel actually used in any particular solution of a task on mission network. Subtasks will be considered arcs or activities of a task or mission network. The subtask A in Figure 2 is represented as arc or activity (i,j). The nodes at the beginning and end of a subtask arc represent points in time. The node at the beginning of arc (i,j) Figure 2 represents the start time of the subtask and the node at the end of the arc represents the completion time of the subtask (i,j). The parameters of subtask or arc (i,j) may be identified by using the (i,j) postscript. U, L, CN, CC and CA for subtask (i,j) may now be redesignated as U(i,j), L(i,j), CN(i,j), CC(i,j) and CA(i,j), respectively.

By joining the component subtasks in the required order, a sequence of arcs or activities is formed which represents a task network. The number of possible networks for each

SUBTASK TIME-COST TRADE-OFF GRAPH



U - SUBTASK NORMAL COMPLETION TIME

L - SUBTASK CRASH COMPLETION TIME

CN - SUBTASK NORMAL PERSONNEL COST

CC - SUBTASK CRASH PERSONNEL COST

FIGURE 1

ARC REPRESENTATION OF SUBTASK

$$i \xrightarrow[\text{CN , CA , CC}]{\text{L , U}} j$$

U - SUBTASK NORMAL COMPLETION TIME

L - SUBTASK CRASH COMPLETION TIME

CN - SUBTASK NORMAL PERSONNEL COST

CC - SUBTASK CRASH PERSONNEL COST

CA - SUBTASK ACTUAL PERSONNEL COST

$CN \leq CA \leq CC$

i - TAIL NODE OF ARC(SUBTASK) (i,j)

j - HEAD NODE OF ARC(SUBTASK) (i,j)

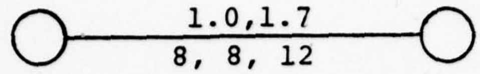
FIGURE 2

task will be the product of the number of methods to accomplish each subtask.

To provide examples and to set the stage for a presentation of larger mission networks, task networks will be shown for three tasks. The general assumptions for all the subtasks and tasks are as follows:

1. each task is to be executed by a combat engineer squad consisting of one squad leader, one vehicle operator and six combat engineers.
2. additional combat engineers are available from the parent platoon.
3. the combat engineers are equal in ability and are capable of setting and priming demolition charges.

The parameter values given for each subtask's CN, CC, U, and L were estimates based on the performance rates in the Family of Engineer Systems Study data base [9]. For example, using the rate of one charge per man per hour for the unloading and preparation of cratering charges, it was estimated that to set ten cratering charges it would take the six combat engineers in a squad, 1.7 hours. If the squad was augmented by four combat engineers, it would take only one hour. The squad would normally use all six combat engineers if available, and an augmentation of four would be the most needed. Therefore, for this task, the normal cost (CN) would be eight, the normal time (U) would be 1.7 hours, the crash cost (CC) would be twelve men and the crash time (L) would be one hour. The subtask's arc is given on the next page.



Although the subtask normally requires only six combat engineers, the normal subtask cost is given as eight personnel. The additional two personnel for the subtask account for the squad vehicle operator and the squad leader. Neither the squad leader nor the operator are considered in the subtask performance rates, but are certainly necessary. The squad leader is considered in the subtask performance rates for site reconnaissance and demolition firing subtasks of tasks to be presented.

The first task to be modeled is Task (1,1,1) install a point minefield providing a 35 meter radius coverage. The two methods of execution are the modular packed mines system (MOPMS) and hand emplacement. The MOPMS consists of an assortment of 21 anti-tank and anti-personnel mines loaded on a pallet. The mines are ejected from the pallet explosively and disperse over a 180 degree fan in an area of 70 meters by 35 meters. This particular task requires three pallets. If hand emplacement is used 30 anti-tank mines and three anti-personnel mines are required.

The second task to be modeled is Task (1,1,8), crater an asphalt road, 25 feet in width. There are two methods of execution considered. The first method is the M180 cratering kit which is self contained and requires no preliminary excavation. Each kit yields a hole with a depth

of six to nine feet and a diameter of 12 to 22 feet. To complete this task requires four kits. The second method of execution uses shaped and cratering charges which requires three shaped charges and ten cratering charges.

The last task considered is Task (1,1,6), which is to disable a class 60 bridge with one intermediate support and steel stringers. Only one method is considered. The far abutment, the intermediate support and the stringers of the bridge will all be destroyed by demolition. This task requires three shaped charges, three cratering charges and 160 pounds of explosives.

Given the preceding representation of the three tasks (Tables VIII, IX and X), it is now possible to join different combinations of those networks to form a larger "mission" network. This network may be considered as the graphical representation of a mission given to a combat engineer platoon. Assuming the platoon has been ordered to accomplish the three tasks, the questions are as follows:

1. Can the platoon accomplish all three tasks concurrently?
2. Given that the platoon only has particular equipment, supplies and personnel available, which methods of task execution should be used so as to require the smallest number of personnel to accomplish the overall mission in the minimal time.

Some of the questions confronting the platoon leader are given in the preceding discussions. The answers to these questions for missions, in general, will be critical in answering the training questions:

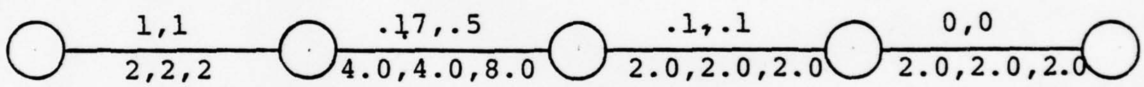
TABLE V

<u>TASK(1,1,1) – POINT MINEFIELD EMPLACEMENT</u>
(35 meter radius)

Technique A - MOPMS

	1 - Subtasks	Performance Rate	U	CN	L	CC
A	Site Reconnaissance	2mcn/hour	1	2	1	2
B	Unloading and Preparation	6 pallets/2 men/ hr	.5	4	.17	8
C	Recording	2 men/.1 hr	2	.1	2	.1
D	Firing	2 men (immediate)	2	0	2	0

2 - Network



Technique B - Hand Emplacement

	1 - Subtasks	Performance Rate	U	CN	L	CC
A	Site Reconnaissance	2 men/1 hr	1	2	1	2
B	Unloading + During	4 a.t. mines/ man/hr 8 a.p. mines/ man/hr	1.4	8	.7	14
C	Recording	2 men/.1 hr	2	.1	2	.1

Network

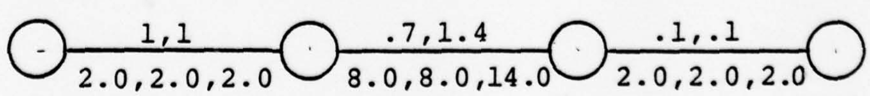


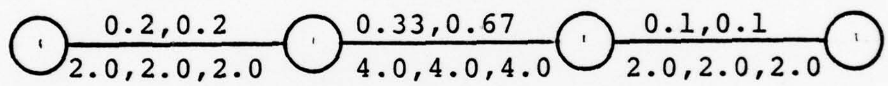
TABLE VI

TASK(1,1,8) - CRATER A ROAD
(asphalt, 25 feet wide)

Technique A - M180 Cratering Kit

	1 - Subtasks	Performance Rate	U	CN	L	CC
A	Reconnaissance	2 men/.2 hr	.2	2	.2	2
B	Unloading, preparing, firing	1 kit/2 men/10 min	.67	4	.33	6
C	Detonation	2 men/.1 hr	.1	2	.1	2

2- Network



Technique B - Shaped and Cratering Charges

	1 - Subtasks	Performance Rate	U	CN	L	CC
A	Reconnaissance	2 men/1 hr	1	2	1	2
B	Prepared and fire shaped charges	1 charge/2 men/ .5 hr	1.0	8	.5	14
C	Prepare and fire cratering charges	1 charge/man/hr	1.7	[illegible]	1.0	12
D	Detonation of bridge	2 men/immediate (non-engineers)	0	0	0	0

2 - Network

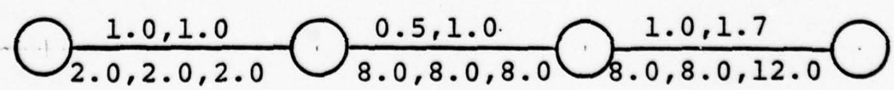
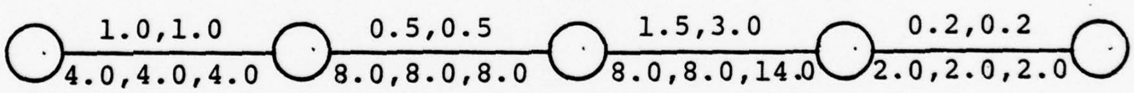


TABLE VII

TASK(1,1,6)— DISABLE BRIDGE
(Class 60,1 Intermediate Support, Steel Stringers)

	1 - Subtasks	Performance Rate	U	CN	L	CC
A	Bridge reconnaissance	3 men/1 hr	1	3	1	3
B	Unload, prepare and fire shaped charges	1 charge/man/ .5 hr	.5	8	.5	8
C	Place intermediate, stringer and cratering charges	1 charge/man/hr	3	8	1.5	14
D	Detonate	2 men/.2 hr	.2	2	.2	2

2 - Network



1. Anticipating the most likely missions to be executed and the equipment and supplies most likely to be available, on which methods should engineer unit training managers concentrate their training?

2. Given the training methods, which subtasks are critical and what are the required training standards for those tasks?

In order to address the preceding questions, it is necessary to take the task networks and join them into a mission/project network. The graphic representation of a resulting network is shown in Figure 3. This particular network uses the hand emplacement method for the minefield task and the shaped and cratering charges method for the road cratering task. To form the network all initial subtasks for each task network originate from the same node. The task networks then proceed in the same sequence as before, finally being joined together at the final node. In the mission network of the three tasks in Figure 3 it was necessary to converge the three task networks before the final subtask of disabling the bridge. This convergence was done to insure that all personnel were on the "friendly" side of the river before destroying the bridge. When combining smaller networks into larger systems, required precedence relationships between elements of different sub-networks must be maintained. The numbers in each node in Figure 3 are used to distinguish the subtasks in the project network. Subtask A of the minefield task can now be referenced as arc or activity (1,2). Activity (8,10) is a subtask that did not exist in the minefield task network. This arc was

INITIAL NETWORK WITHOUT M180 OR MOPMS

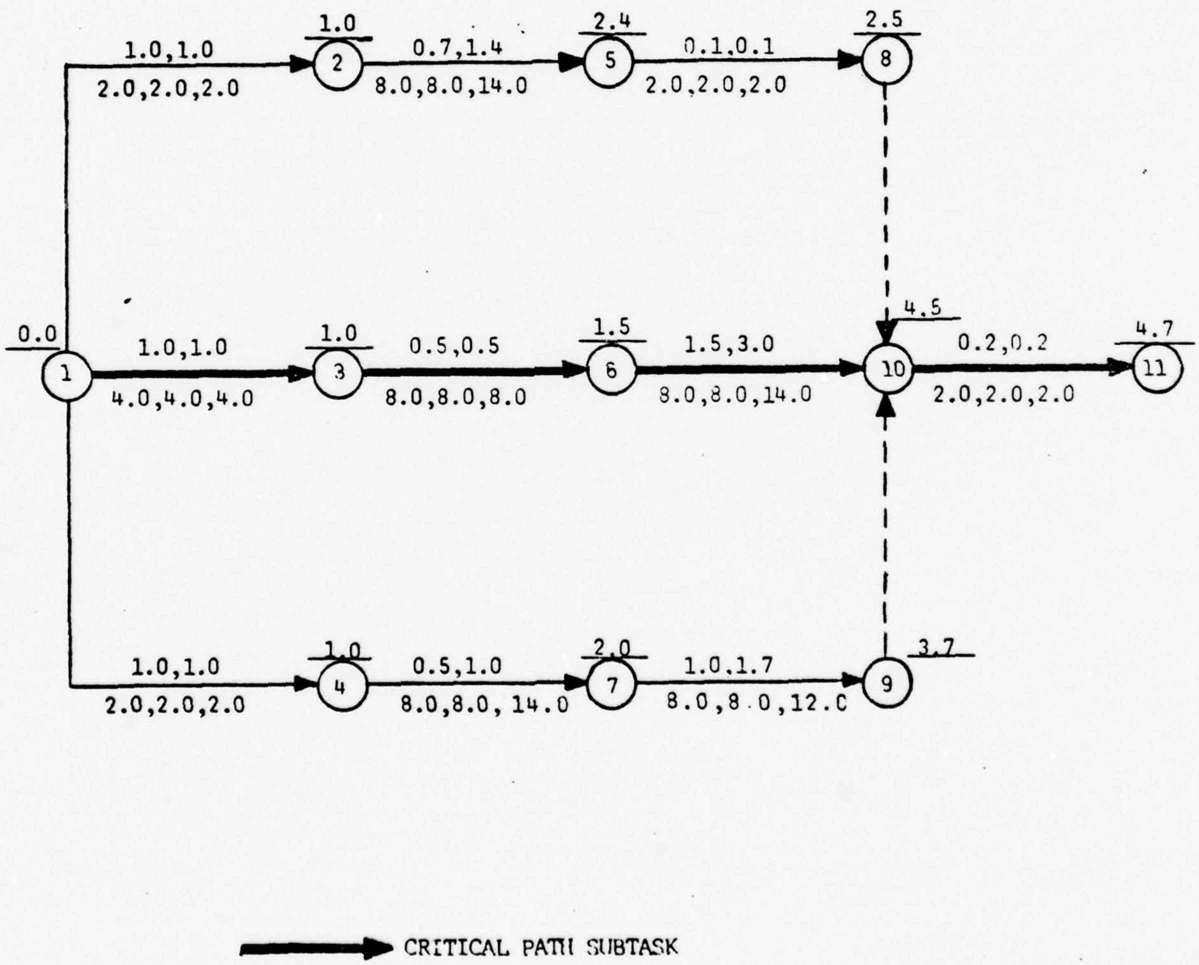


FIGURE 3

placed into the mission network to show the precedence relationship of completing the minefield task before felling the bridge. In Figure 3, the numbers above the events are the project's duration time at each node and are represented algebraically as V(i), for example, V(5) represents the time the project has been in progress at node five. The initial node of a network will have V(i) equal to zero and the final node of a network will have a V(i) value equal to the time required to complete the entire project. In Figure 3 V(11) is the entire project duration and its value is 4.7 hours, with all subtasks completed in normal time.

D. CRITICAL PATH TIME COST TRADE-OFF PROCEDURE ANALYSIS

The network technique proposed to assist in addressing the questions is the Critical Path Method Time Cost Trade-Off Procedure (CPMTC). CPMTC basically utilizes a project network (in this discussion the project will be the three task mission) and provides a process for analyzing the subtasks' time-personnel trade-off graphs. It adjusts the graphs to minimize the cost of personnel required to complete the project within a particular duration, eventually providing the minimal project duration at the lowest feasible personnel cost. The process evolves from the normal project duration, using subtasks' normal times to determine the minimal project duration; and using a combination of subtasks' cost for that duration. The end result is a time-cost personnel trade-off graph for the entire project.

The basic procedure is to start at the normal project duration and then successively reduce the duration for the least cost activity on the critical path, until the minimum project duration is reached. The final solution is the minimal project duration using the least number of personnel for that duration.

Figure 3 represents the initial network in the CPMTC sequence of feasible networks. Each subsequent network represents a decreased project duration obtained through a minimal increase in cost. The total project duration of the initial network in Figure 3 is V(11), which equals 4.7 hours. The total project duration for any of the network solutions is the time required to complete the longest time path through the network (critical path). In the initial network, the time required to complete each subtask is the subtask's normal time, U(i,j). The critical path of the network in Figure 3 is the sequence of nodes 1; 3; 6; 10; 11; the bridge disabling task. This path is called critical because delay of any subtask on it will cause the same delay in the overall project completion.

The corresponding project cost for any project duration is equal to the sum of the maximum subtask costs for each task in the network. For example, the maximum subtasks normal costs for each task of Figure 3 are: subtask (2,5) with the normal cost equal to 8 personnel for the minefield task; subtasks (3,6) or (6,10) with normal costs equal to

eight personnel for the bridge disable task; and subtasks (4,7) or (7,9) with normal costs equal to eight personnel for the road crater task. Therefore, the project cost (CN) for this network with all subtasks at normal duration and normal costs is equal to 24 personnel.

Having established the initial feasible network the CPMTC analysis proceeds through the sequence of intermediate networks. Each intermediate solution is found by decreasing the project duration by an incremental amount and by increasing the personnel on the "least expensive" subtask on the critical path. Figure 4 represents the next network solution. In this solution the project duration was decreased by .8 hours by increasing the personnel cost of subtask or arc (6,10) from 8 to 11.2 men. This is represented on the project trade-off graph (Figure 6) as point (3.9,27.2). All intermediate solutions are recorded as points on the project trade-off graph until the final solution is reached (i.e., when it is no longer possible to decrease the project duration time).

Figure 5 is the mission's final network solution. The minimal project duration is 3.2 hours. The lowest project cost for that duration is 34 personnel, point (3.2,34) on the project trade-off graph in Figure 6. This solution was obtained by "crashing" subtasks (6,10) and (7,9) from their normal costs of eight men each to their crashed costs of 14 and 12 men, respectively. There are two critical paths in

INTERMEDIATE NETWORK WITHOUT M180 OR MOPMS

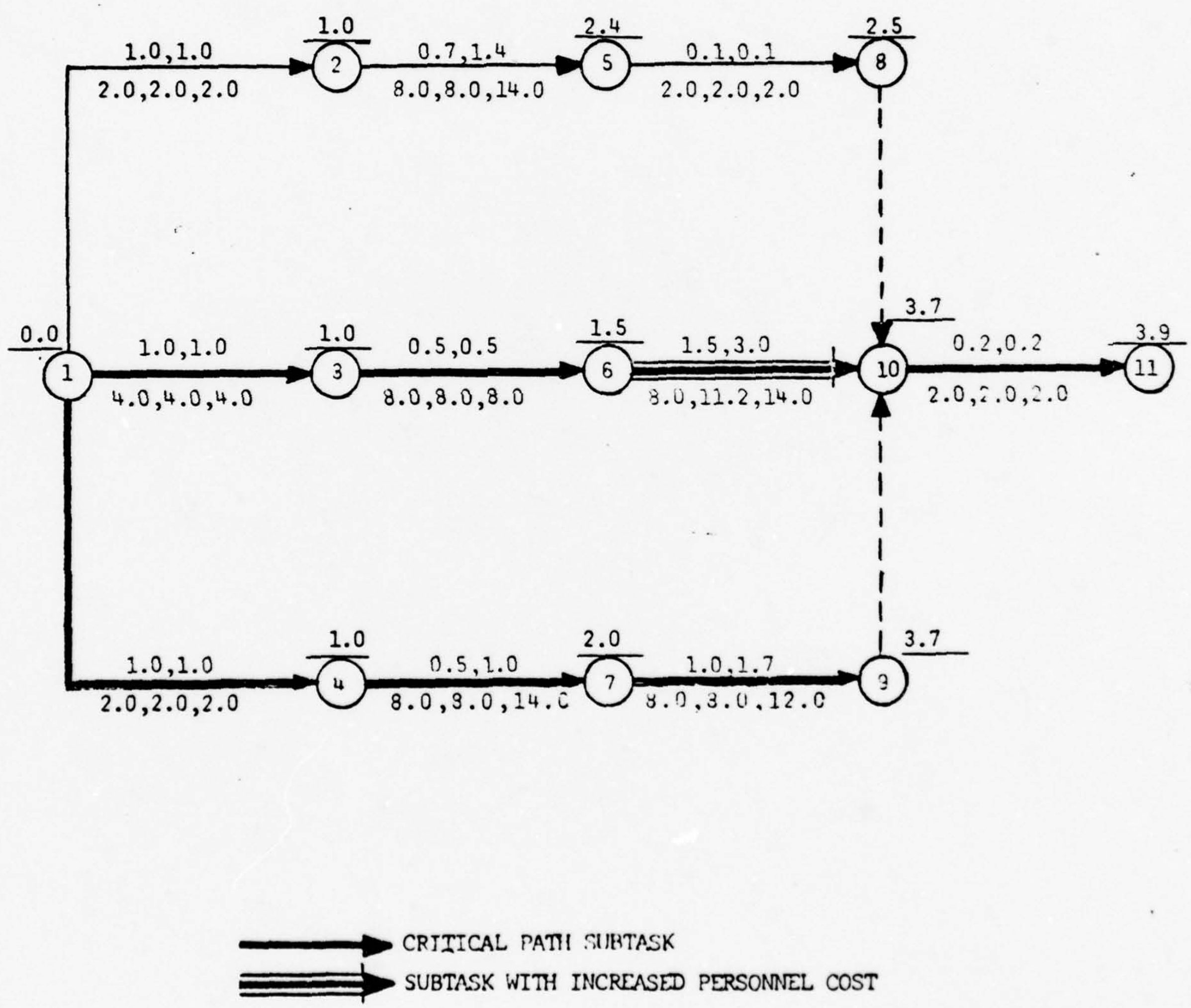


FIGURE 4

FINAL NETWORK WITHOUT M180 OR MOPMS

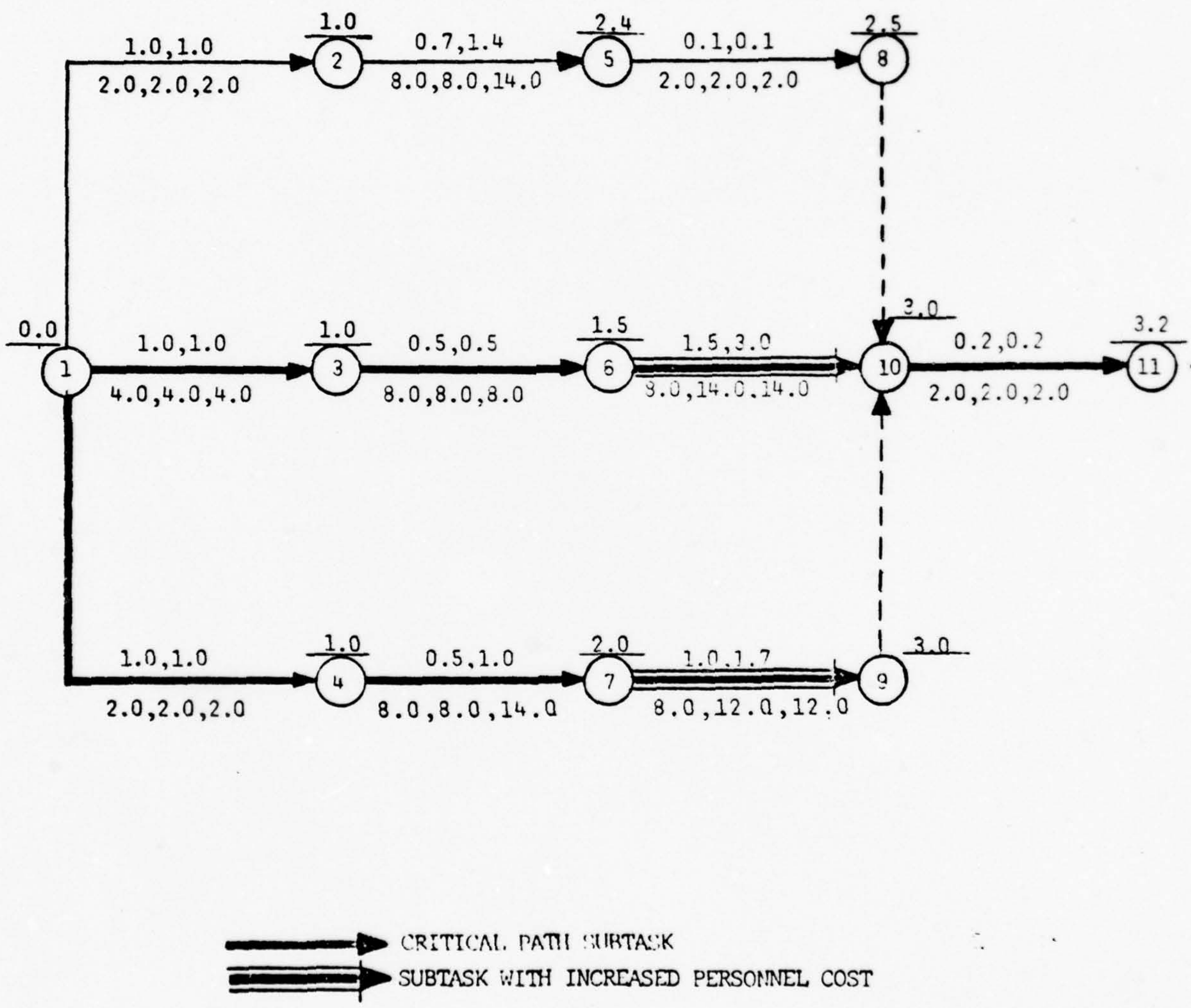


FIGURE 5

TIME-COST TRADE-OFF GRAPH
(WITHOUT M180 & MOPMS)

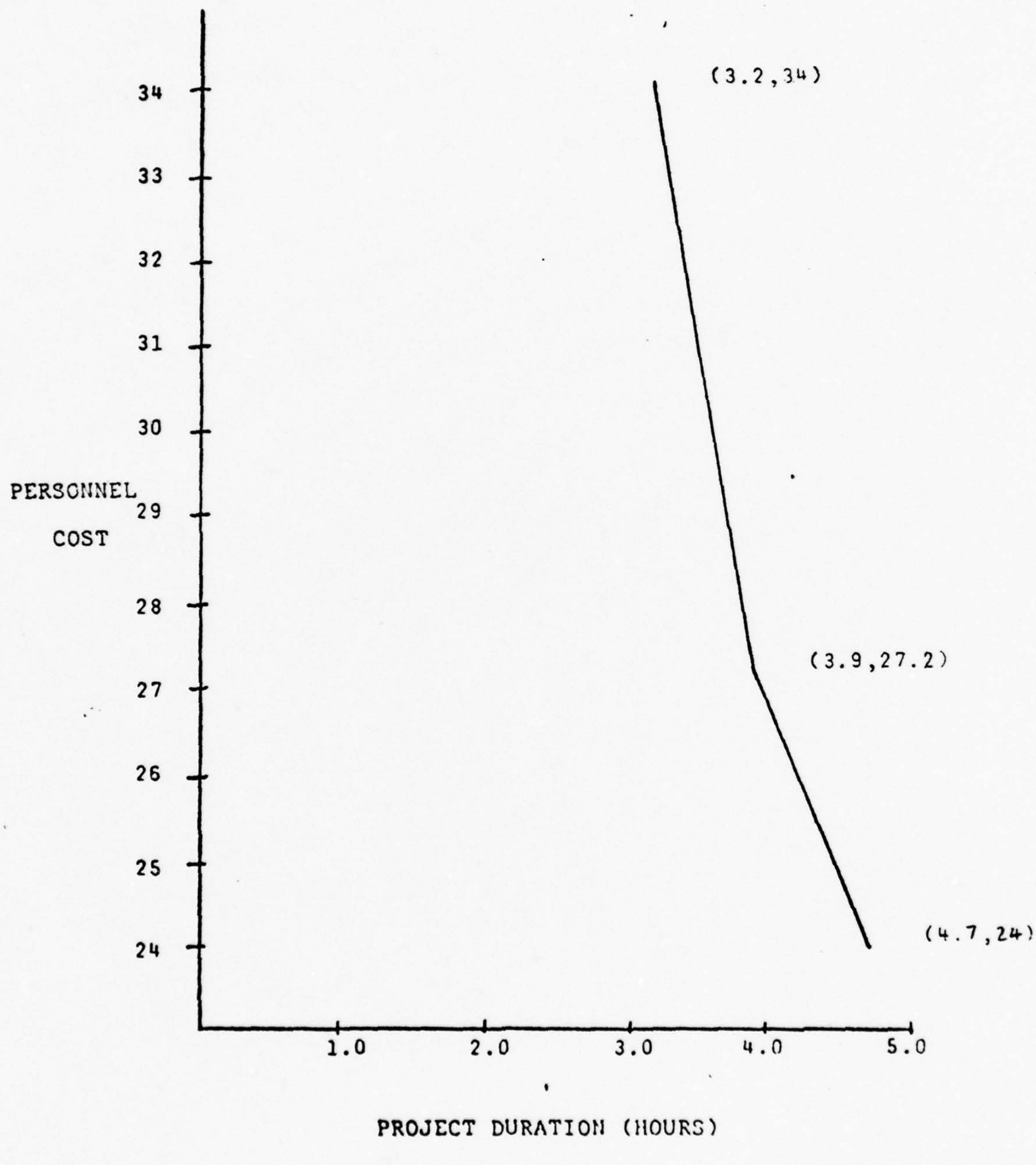


FIGURE 6

the final network shown in Figure 5. The paths are the sequence of nodes 1; 3; 6; 10; 11 and 1; 4; 7; 9; 10; 11.

The lines connecting the solution points on the project trade-off graph in Figure 6, represent the optimal trade-off "curve" for the project. The "curve" consists of piecewise linear segements. It is possible to have points with non integer personnel solutions. The second network solution (Figure 4) requires 11.2 men for subtask (6,10). This may be interpreted as being equivalent to having one man for 0.2 of the subtasks duration. Any point on the curve represents the minimal number of personnel required to perform the project within a specified duration, given the particular methods of executing each task.

Thus, should the platoon leader not have the MOPMS mine system and the M180 cratering kit available, this trade-off graph will assist him in determining the necessary length of time to accomplish the mission, given a specified number of men, or how many men it will take to complete the mission in a specified amount of time. Once he has determined the applicable point on the trade-off graph, he can use the network to establish the subtasks' time and personnel requirements. Then Critical Path Methods can be employed to actually manage the execution of the mission.

The preceding network and trade-off curve assumed that the minefield task was done by hand and the cratering of the road was done by cratering charges. Figure 7 shows the initial solution and Figure 8 shows the final solution to the

INITIAL NETWORK USING M180 AND MOPMS

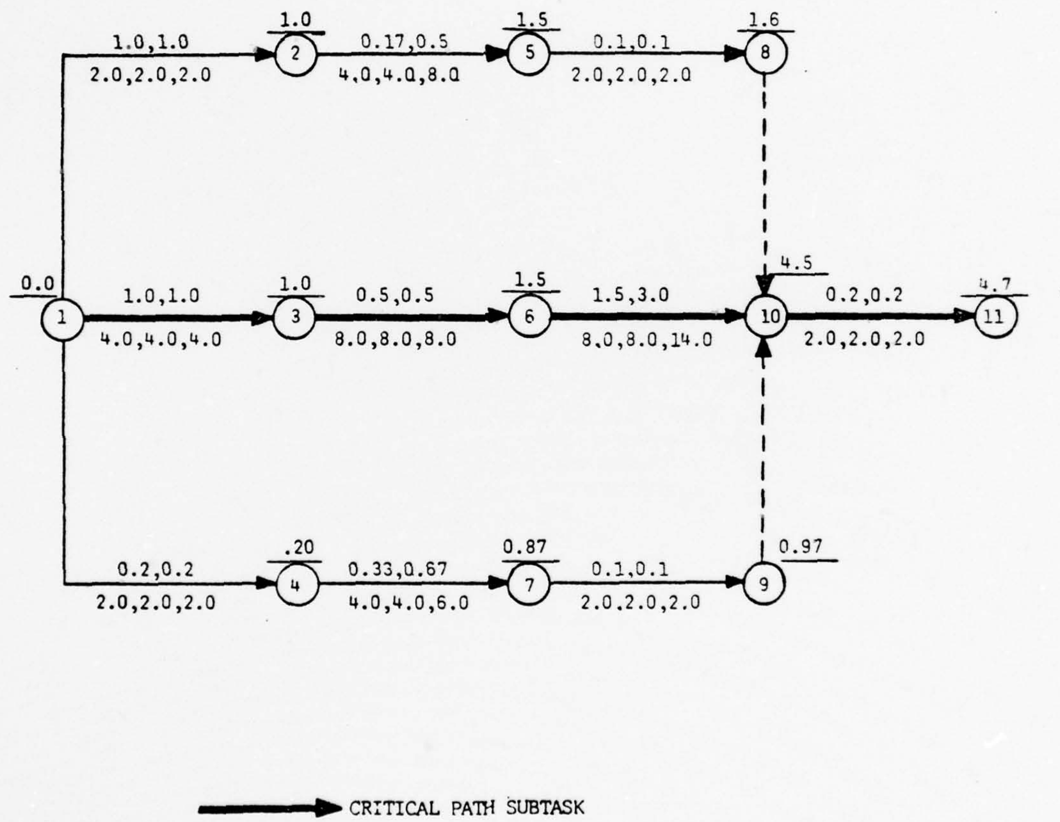


FIGURE 7

FINAL NETWORK USING M180 AND MOPMS

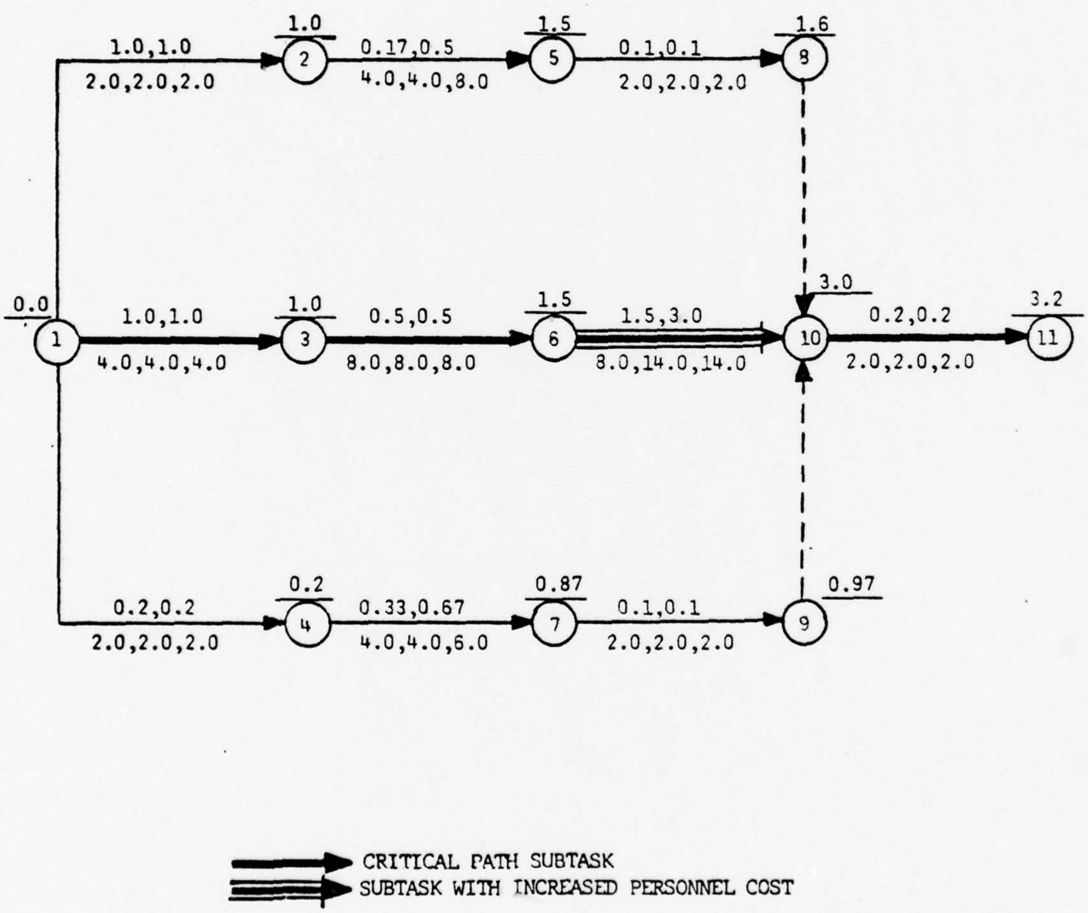


FIGURE 8

project network assuming the use of the MOPMS and the M180 methods. Figure 9 is the trade-off graph assuming the use of those methods. Figures 8 and 9 indicate the project duration was not decreased but the project cost was significantly lowered. Using the previous hand and cratering charge methods, the project's normal cost, CN, was 24 men and the projects' crash cost was 34 men. Using the MOPMS and M180 methods the project's normal cost is 16 men and the crash cost is 22 men. Both methods result in the same initial and minimal project duration. Although the MOPMS and M180 methods were faster and used less personnel, the project durations remained the same because the "disable bridge" task did not change and is the critical path for both networks. In the discussion of possible techniques for executing the bridge disabling task, there were no other techniques accepted, implying that this mission duration cannot be reduced. If the mission were altered so that the disable bridge task was not included, the reduced times of the MOPMS and M180 methods could be utilized.

Figures 10, 11 and 12 are the initial project network, final project network and trade-off graph, respecitvely, of the mission without the disable bridge task and assuming the use of MOPMS and M180 methods. Using the normal costs for each subtask, the normal project duration is 1.6 hours. The minimal project duration is reached by "crashing" or increasing the personnel for subtask (2,5) to its crash cost

TIME-COST TRADE-OFF GRAPH
(USING M180 & MOPMS)

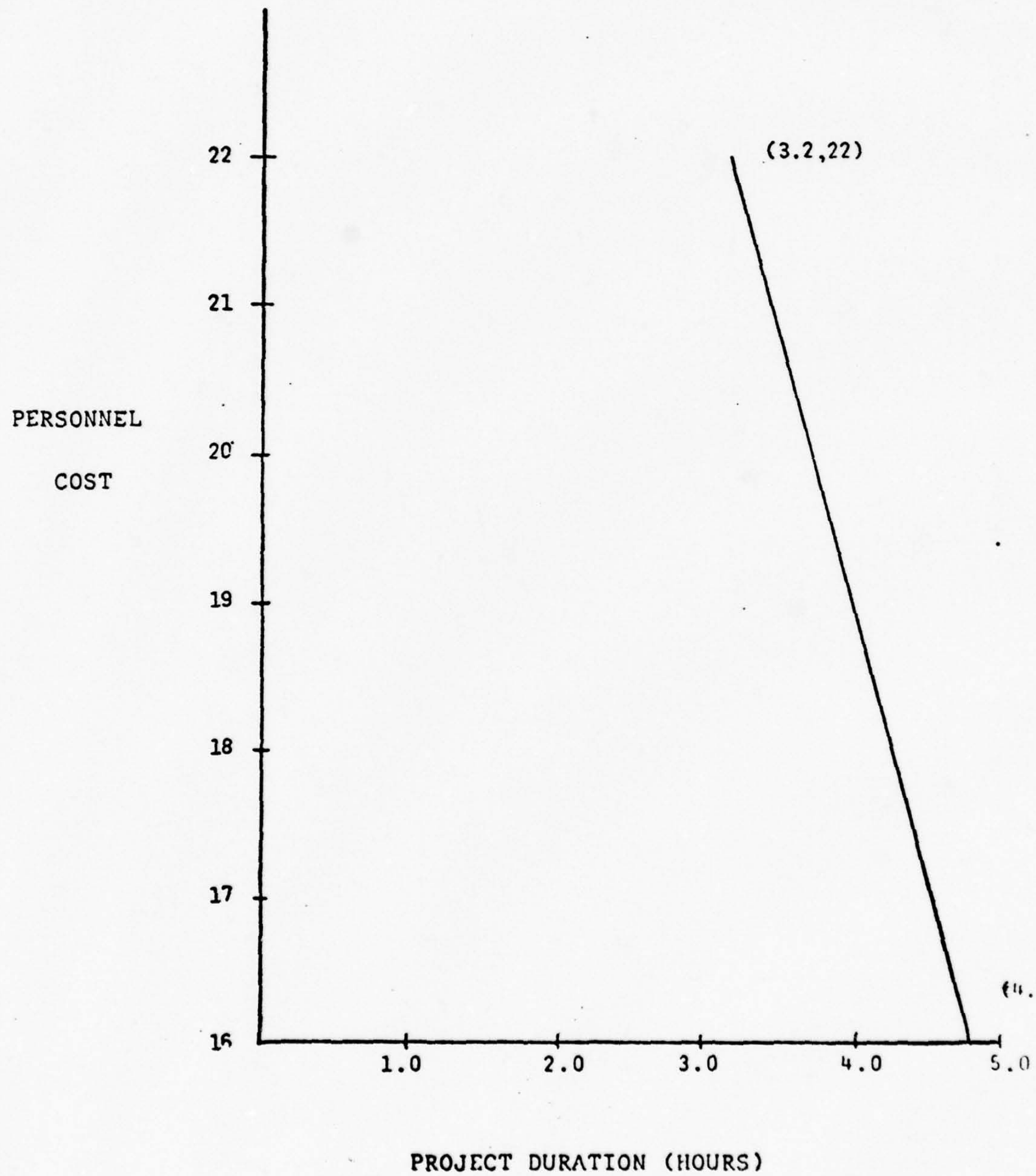


FIGURE 9

INITIAL NETWORK USING M180 AND MOPMS
(NO BRIDGE DISABLE TASK)

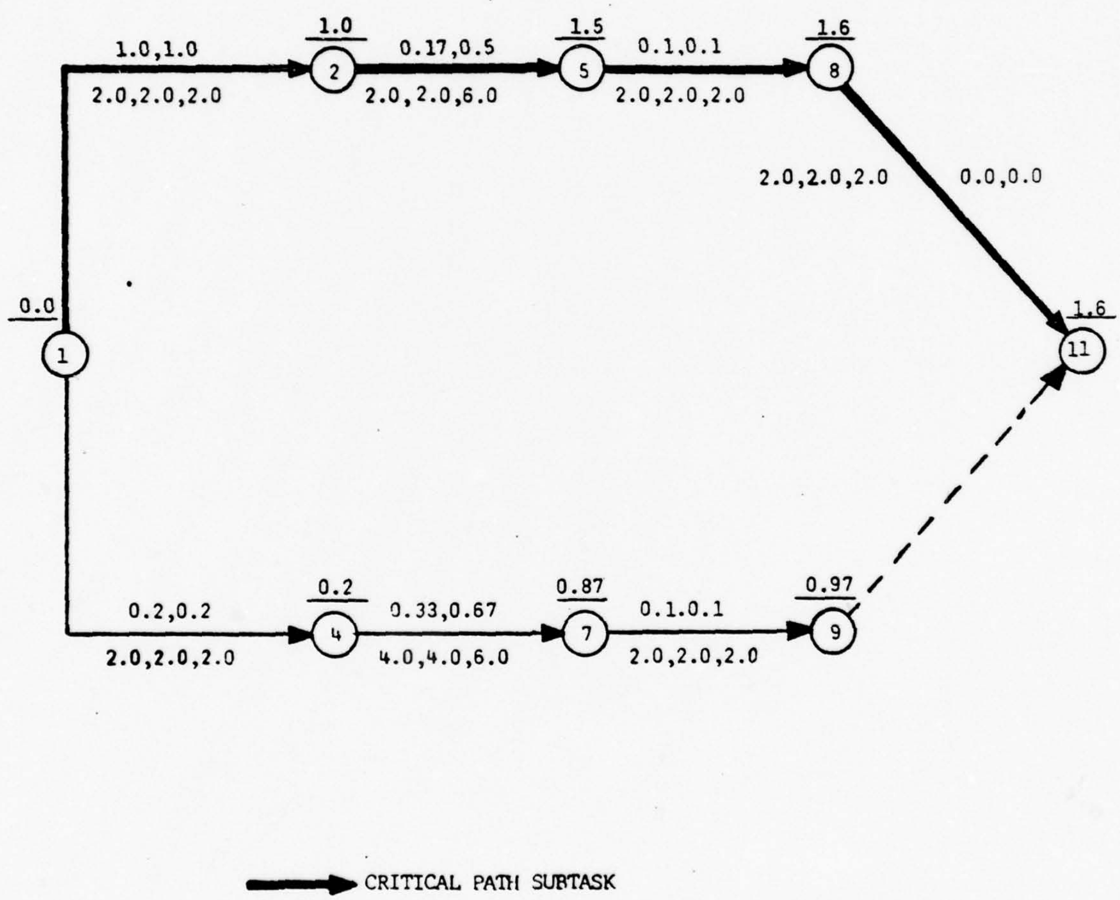


FIGURE 10

FINAL NETWORK USING M180 AND MOPMS
(NO BRIDGE DISABLE TASK)

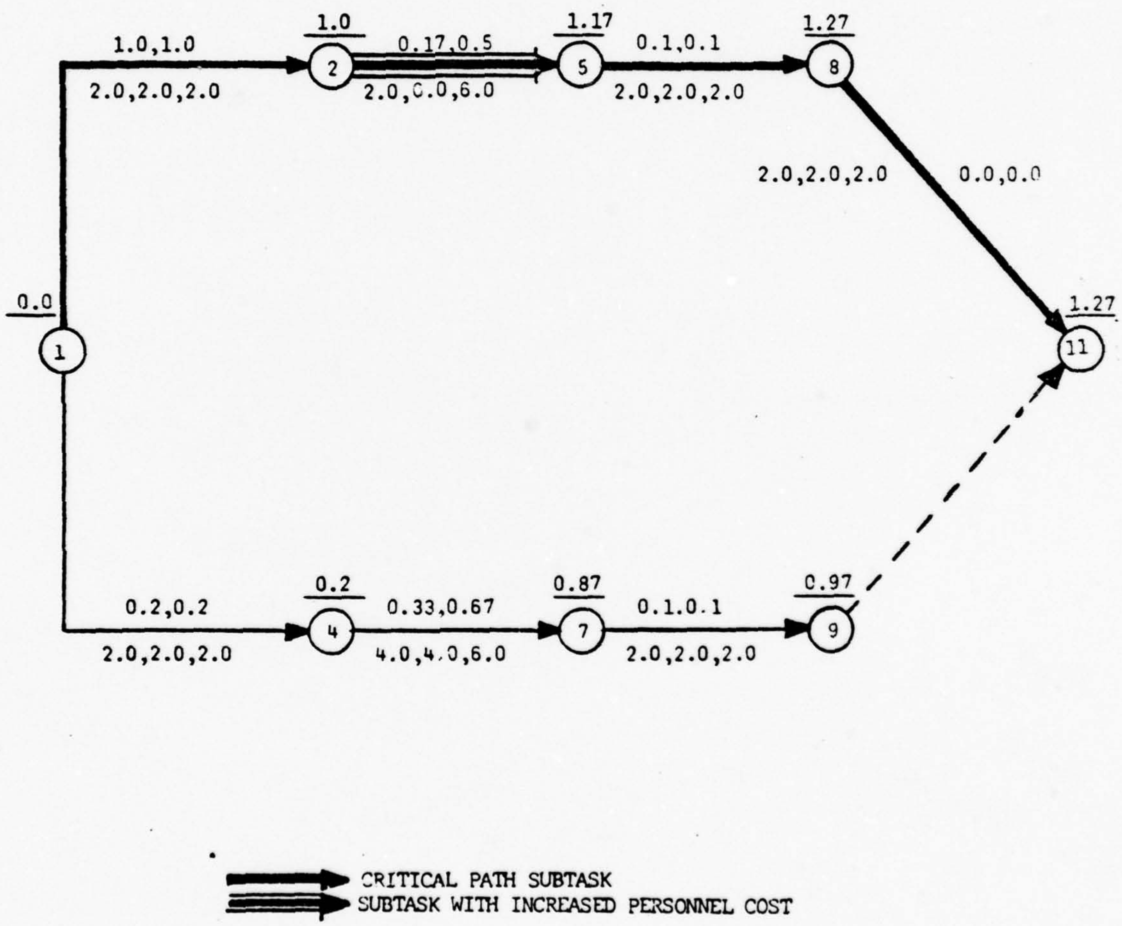


FIGURE 11

TIME-COST TRADE-OFF GRAPH
(WITHOUT DISABLE BRIDGE TASK)

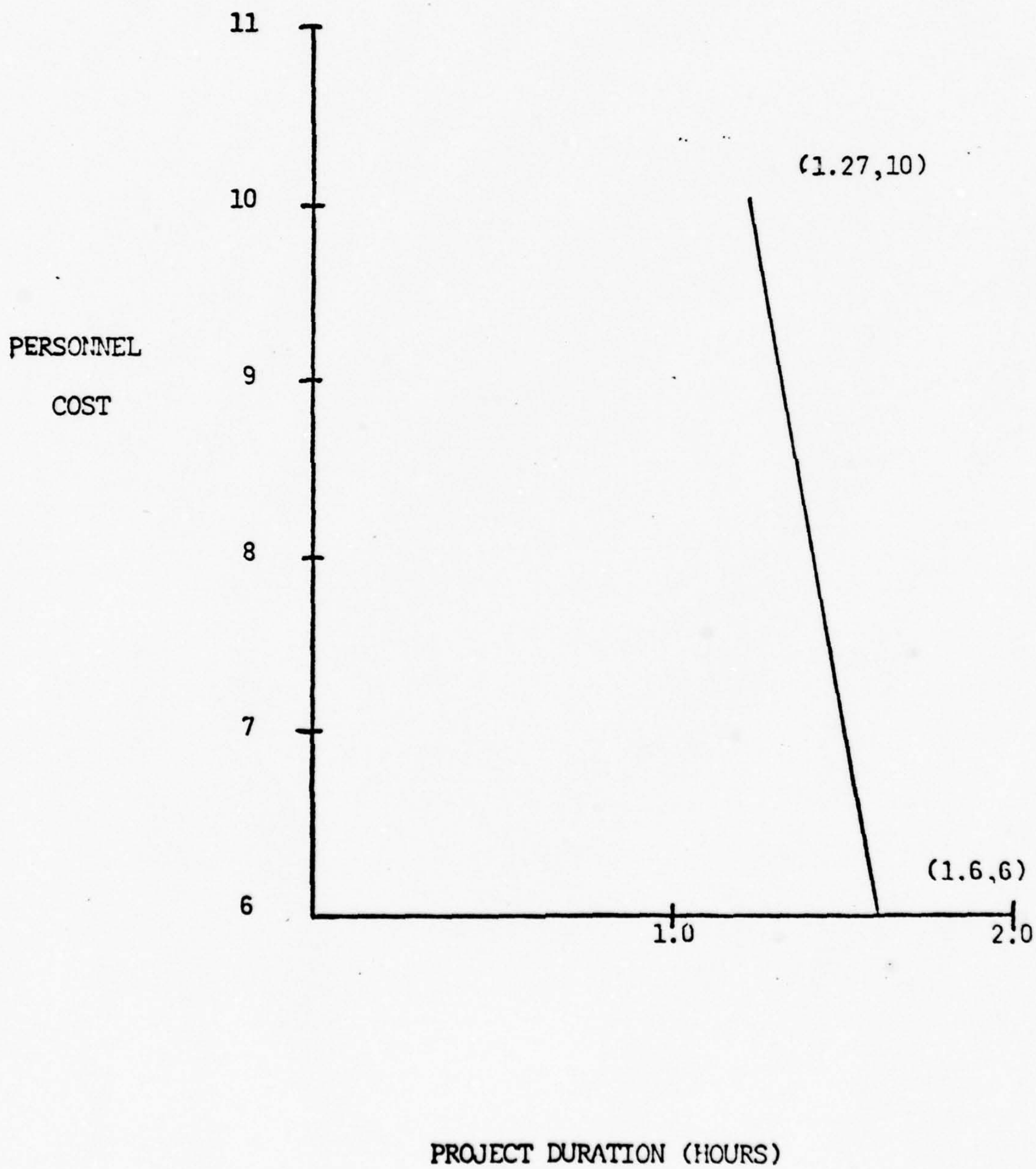


FIGURE 12

of six. Both the normal project cost and the crash project cost are kept two men lower by having the two personnel from subtask (4,7) help on subtask (2,5).

Figure 13 illustrates the time-cost trade-off graph comparing the time trade-off curves of mission variations discussed. With this graph it is possible to address the questions originally confronting the platoon leader. Curves B and C represent the original mission of three tasks, the only difference being the methods of task execution. Clearly, curve B dominates curve C in minimizing project cost over their common range of feasible project durations. Given that the MOPMS and M180 systems are available in sufficient quantities, the platoon leader should utilize them. Curve A not only dominates curves B and C in minimal project cost, but also in feasible project duration. Although curve A has a glaring dominance, it is deceptive because the mission it represents does not include the disable bridge task. Certainly, if the only feasible project duration was below three hours or the number of personnel available was below 13, curve A would be the platoon leader's only choice of the three presented.

Although this analysis was accomplished using only three of the many tasks considered critical and involved only a platoon mission, it can be applied to many of the elements involved in engineer ARTEP training. The CPMTC technique can be used by an external evaluator of an engineer unit to

TIME-COST TRADE-OFF FOR THE THREE PROJECT NETWORKS

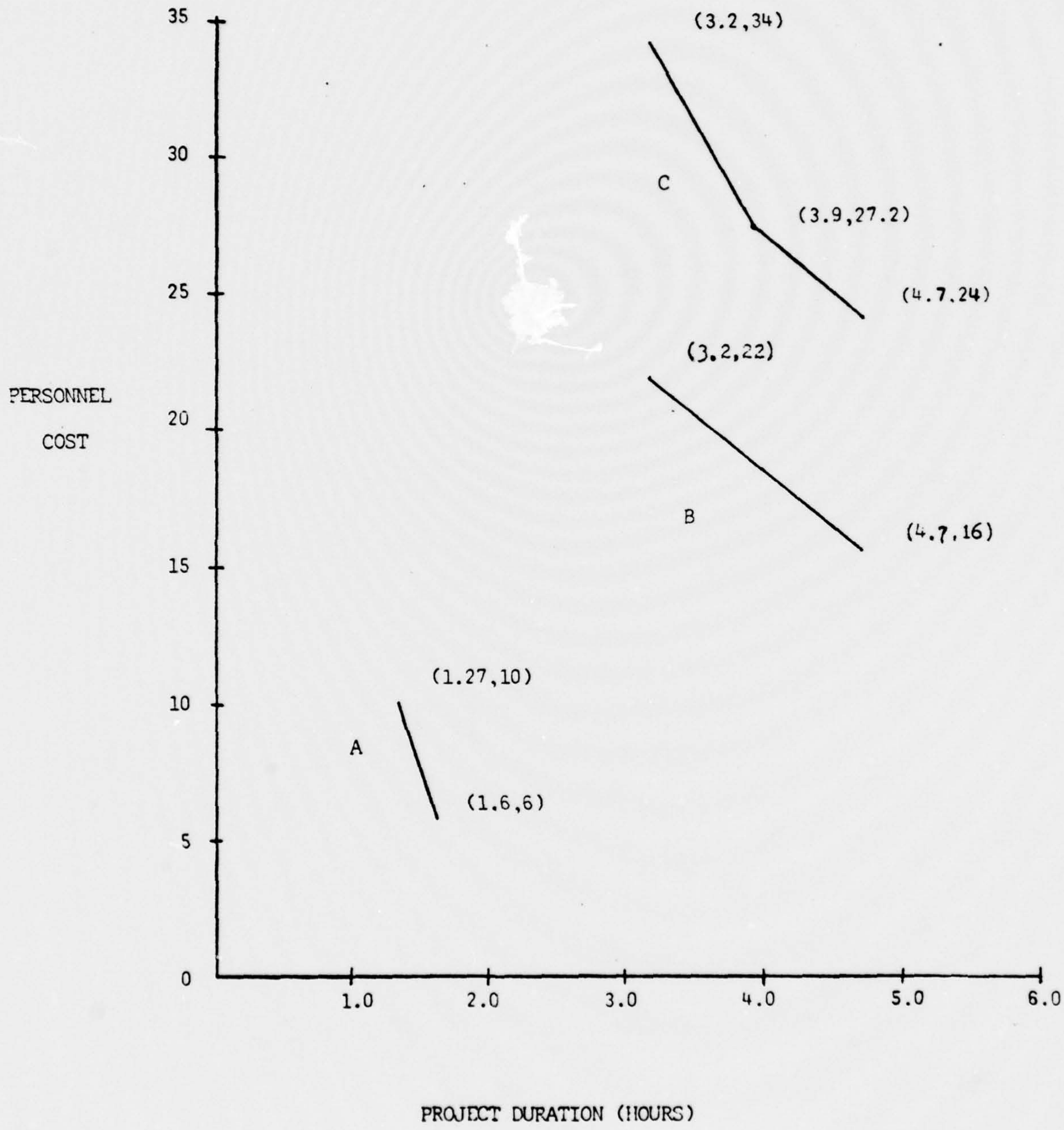


FIGURE 13

determine the feasibility of mission assignments. The results of his analysis can be used to develop the scenario for the evaluation. Any engineer unit commander assigned a multiple task mission in an external evaluation could use CPMTC analysis to allocate his resources. In addition to its use in evaluations, CPMTC has potential use as a training tool. Use of CPMTC analysis as an integral part of task and mission training will enable engineer commanders and their subordinates to become and remain familiar with the relationships of personnel, equipment and time in the execution of the tasks and missions. The results of CPMTC analysis can provide information concerning which tasks or subtasks should receive training emphasis in order to reduce mission durations or resource requirements. Using these techniques, the U.S. Army Engineer School can compare methods of execution of tasks and determine future training and hardware developments.

The methodology and techniques in this chapter address measures of performance of tasks and missions (the personnel, equipment and time required). The question of task effectiveness remains unanswered. Once again consider the platoon leader's problem and the trade-off curve in Figure 13. If curve B was in the feasible range of the platoon leader's resource constraints, should the disable bridge task be executed (i.e., is it worth the increased time and personnel)? To answer that question, it is necessary to determine the disable bridge task's overall combined arms effectiveness.

In the next chapter a proposed engineer training system will be presented. The system uses the techniques of this chapter to provide a methodology to answer the questions of task effectiveness and task training priorities.

IV. PROPOSED ARMY TRAINING SYSTEM

The effectiveness of all critical engineer tasks must be determined in terms of their worth to the combined arms team. The engineers must concentrate their training on those tasks which maximize the combined arms effectiveness on the battlefield. Ultimately, all combined arms tasks must be measured and compared in these terms.

In this chapter a training system will be presented that proposes changes and additions to the present ARTEP collective training system discussed in Chapter II. The proposed training system represents a methodology to manage Army training to enhance the combined arms team's ability to win the land battle. The engineer components and applications of the training system will be presented in the context of the overall system description.

The flowgraph of the system to be described is shown in Figure 14. Each box represents an element in the training system. The system can be viewed as two groups of elements. The left column is composed of elements of the present ARTEP training system. Element one represents the Training and Doctrine Command (TRADOC) headquarters and its proponent schools — including the United States Army Engineer School (USAES). Element two is the combined arms units in the field. The training system presented concerns the combat units from squad to corps level. ARTEP external evaluator

PROPOSED ARMY TRAINING SYSTEM

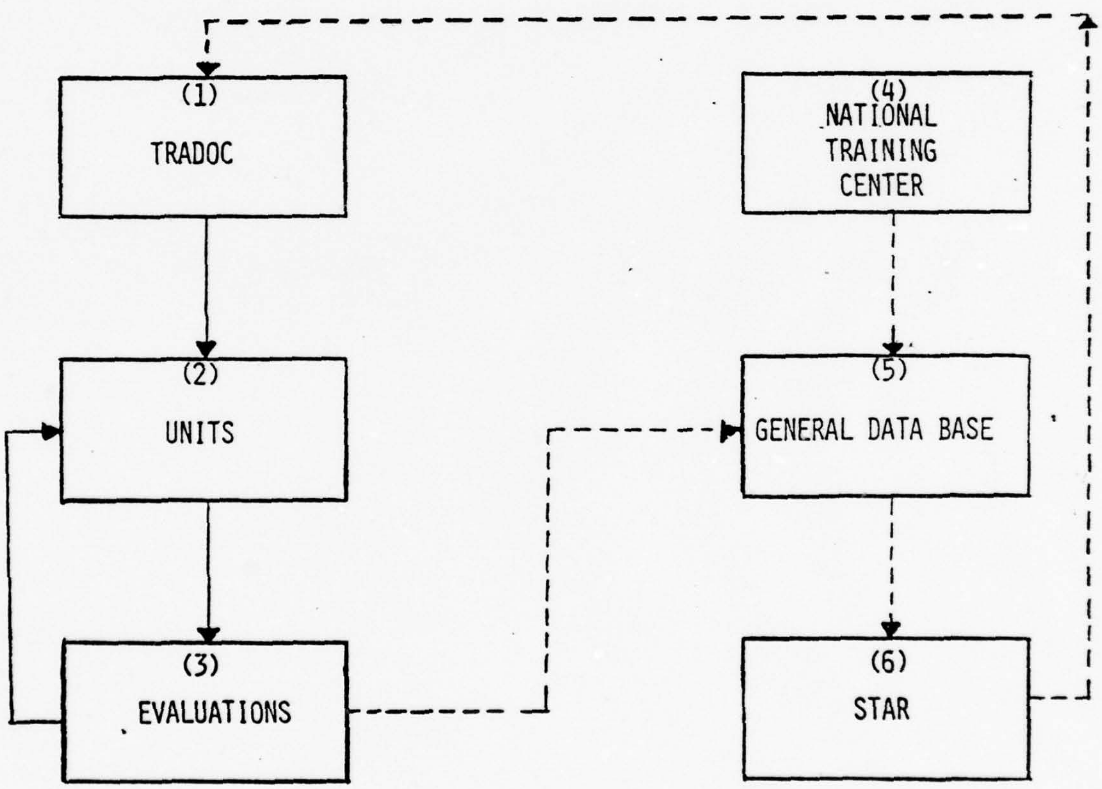


FIGURE 14

of the combat units are the third element of the training system.

The right column of elements in the training system consists of proposed additions to the present ARTEP system. The National Training Center addressed in Chapter II is element four. Element five is a General Data Base that provides training data storage for other elements of the system. The Simulation of Tactical Alternative Responses (STAR), element six, is a combined arms combat model used to develop training measures of effectiveness for the proposed training system.

The arcs in the training system flowgraph (Figure 14) indicate the direction of information flow from one element to another. The solid arcs indicate information channels that presently exist and the dashed arcs represent proposed channels. The system as shown is a closed-loop system and the flow of information throughout the system is continuous.

TRADOC (element one) is responsible for the doctrine and overall direction of training. In the proposed system it is TRADOC's responsibility to direct training changes and refinements based on the feedback from the system itself. In terms of the engineer family, USAES has the responsibility to analyze the feedback from the system with respect to engineer training requirements. The results of this analysis should be channeled back into the system in the form of changes or updates to engineer units' training requirements. Obviously, TRADOC and the proponent schools exist and training

requirements have been channeled from the schools to their respective units through the distribution of the ARTEP. What does not currently exist is an effective feedback channel to TRADOC elements providing comments concerning the results of the application of the ARTEP. Without an effective feedback channel, TRADOC cannot direct the present or proposed training systems. The information required and the channel will be described in a subsequent section.

In the present ARTEP system commanders of the combat units (element 2, Figure 14) have the responsibility to develop their unit's ARTEP based on the training guidance from TRADOC (USAES for the engineer units). As previously stated, commanders conduct their training based on expected missions and perceived training status. For the proposed training system this remains unchanged, since the commanders know best the requirements of their situation. One of the goals of the changes and additions recommended in the proposed training system is to enable the field commanders to construct and adjust their units' ARTEP using the best information available.

The evaluation of a units' training is element three. As presented in Chapter II, the evaluation is done using the standards established by the proponent TRADOC school. The unit's responsibility is to train to those standards and to adjust future training based on the evaluation results. In Figure 14, the necessary feedback channel of evaluation

results is represented by the arc from evaluations back to the units. At present units are not required to provide any information on the results to any member of the TRADOC family. Thus, there is no feedback to the personnel responsible for establishing and updating the training standards. The Engineer School has received very few ARTEP evaluation reports from the field. Proposed changes and additions to the present training system begin with these evaluations.

Following the present ARTEP guidelines, external evaluations should be conducted by highly qualified personnel in the combined arms combat environment. Adhering to these guidelines requires an extensive use of resources. At present, the evaluations obtained for the large resource expenditure go only to the unit evaluated. The benefit of these evaluations can be increased if the information generated by an external evaluation could be recorded, stored and used by other elements of the training system. The tasks performed by evaluated units are precisely those tasks TRADOC has established as critical and for which data will have to be collected and analyzed. TRADOC should have field data to monitor the ARTEP training system's progress towards the ultimate objective of winning the land battle. The USAES receives no feedback to determine whether the critical tasks listed in the ARTEP manuals are actually considered critical by units, or even if the standards for the tasks are feasible. The tasks and standards are not static; they must be changed and

updated to reflect field training and hardware development results. The question of collecting the results of external evaluations is not, should it be done – but how to do it.

The present system of voluntary reporting of ARTEP evaluations results is failing. To send data collectors from the schools on a full-time basis would be too expensive and too little data would be generated on a part-time basis. A formal channel must be established that is an integral part of the training system. The evaluation should not be considered complete until the results are documented and placed into the informational channel to the General Data Base.

Determining the data to be recorded and the collection procedures is critical to the execution of the external evaluations. Certainly the data needs of the TRADOC family are important, but interrupting the normal flow of evaluations would be detrimental to their primary purpose and also to the accuracy of the data collected. Before the actual evaluation begins, off-line data collection should be accomplished for any data collection requirements that would restrict the natural flow of the evaluation. The data collected should pertain to the measures of performance of the critical tasks- values of variables related to the standards and conditions of performance of the tasks. Each proponent school of TRADOC should develop its own list of critical data to be collected concerning tasks with which it is involved. For engineer tasks, the developments in Chapter III provide a collection

format and the variables on which to collect data. The variables of personnel, equipment and time presented in Chapter III are critical measures of performance for any task. The network representation of subtasks, tasks and missions discussed in Chapter III provides a natural process to collect data regarding each measure of performance for each subtask, task and mission. Using the network format, collection of data on evaluated tasks follows the natural flow of the scenario. The network representation provides a natural format for off-line data collection on specific techniques or equipment not to be used in the evaluation. The network format of data collection is also a convenient format to use for the storage of data to be used in the STAR model, element six in the proposed training system.

In the training system (Figure 14) a proposed information channel goes from the evaluation element to the General Data Base element. The required ARTEP external evaluation reports and data from other training performance sources should be stored in the data base. ARTEP results can be stored in coded form to preserve the anonymity of evaluation results. The data base should be managed by TRADOC and made available to the entire TRADOC family.

The National Training Center (element four, Figure 14) was discussed in Chapter II. The engineer data collection at the center can follow the same format as recommended for ARTEP evaluations. The results of the evaluations conducted at the National Training Center can also be placed in the General Data Base. These results would provide a valuable

source of training performance data collected under the most realistic conditions.

A necessary addition to the proposed evaluation of the training system is a computer (simulation) model that can conceptually combine training and hardware measures of performance in a simulated combined arms battle to determine training measures of effectiveness. The Simulation of Tactical Alternative Responses (STAR) model is a combined arms computer simulation model under development at the Naval Postgraduate School which will meet those needs. Thus, STAR is presented as an integral part of the proposed training system.

The programming language used for STAR is Simscript II.5. The model includes a flexible parametric terrain module that will provide continuous macro-terrain representation. The set structure of Simscript II.5 and the terrain representation will facilitate modeling individual weapon system elements to the brigade level. The goal of the model is to provide the Army with the capability to analyze all facets of the combined arms environment at all hierarchical levels through Corps. To establish a true combined arms environment, development is being conducted across the combined arms spectrum. Functional modules are under development to represent armor and infantry ground systems; field and air defense artillery systems; engineer systems; close air support systems; communications and counter-communications systems;

and ammunition resupply systems. These modules will represent both friendly and enemy elements' performance characteristics.

Simscript II.5 is a discreet event simulation language. An event is an action that occurs such as detect, fire, impact, etc. Events may include the scheduling or cancelling of other events. For example, Emplace.Minefield may be an event. Through Simscript II.5 procedures, Emplace.Minefield may have been scheduled when an armor unit wanted to create an obstacle. The Emplace.Minefield event may calculate how long it will take the engineers to get to the desired minefield location, and schedule the Site.Reconnaissance event (first subtask of minefield task) to begin at the calculated arrival time. The STAR simulated battle time advances only between events. After all changes have been made during an event, the battle time is advanced to the next scheduled event and that event is executed. The battle continues as a sequence of events until battle termination criteria are met. Desired statistics are recorded during the battle and are available for analysis.

Engineer modules for the STAR model have not been developed. The critical engineer tasks are the engineers' contribution to the combined arms team and are a logical choice to represent the engineer system in the STAR model. Network representation appears to be a natural format to follow in modeling the tasks. Each subtask of the network could be considered as two events — one to represent the

starting of the subtask and one to represent the subtask's completion. The time between each subtask's events would be modeled as a function of input values for the measures of performance discussed in Chapter III (i.e., based on the equipment and personnel available) or would be established before the simulation begins. Thus, each critical engineer task could be programmed as a module of specific events in sequence and could easily be emplaced or extracted from the model as desired.

In addition to representing the execution of the tasks, the effects of their execution must also be modeled. A task "execution" variable measures the resources used to accomplish a task and a task "effect" variable measures the results of the task in a combined arms simulation model (STAR) or an actual force-on-force exercise (National Training Center). For example, if the task is to crater a road, then an "effect" variable may be the delay time for the enemy. Thus, an "effect" measure of performance for the task to crater a road would be the value of the delay time to opponent forces measured in a STAR simulation battle or a National Training Center exercise. The value of the "effect" variables will vary with each task's "execution " measures of performance (i.e., the road crater caused by hand emplaced cratering changes may provide more delay than the road crater caused by the M180 cratering kit). Obviously, the tasks' "effect" measures of performance are important in determining the

engineer tasks' contribution to the combined arms team, and the differential values of the "effect" variables are important in the comparison of engineer tasks.

At present, the "effect" variables for each engineer critical task and the procedures to measure them have not been determined. The developers of the STAR model can use their professional judgement to determine the variables and model their estimated effects; but the engineer's, to have credible estimates of their contribution to the combined arms team, must determine the critical tasks' "effect" variables and the procedures to measure them. Once the variables and procedures are established, the data collection and analysis in the proposed training system can be used to validate or change the choice of variables and improve the estimates of effects.

After the development of all the planned combined arms and support modules is completed, the STAR model can be used to determine the combined arms combat effectiveness of the critical engineers tasks. The engineer training measures of performance, represented in the model by the critical tasks, and other combined arms training and hardware measures of performance can interact in the simulated combined arms combat environment of STAR to produce combat measures of effectiveness. The total number of enemy destroyed and the number of friendly forces remaining are two combat measures of effectiveness. Conducting sensitivity analysis with and

without the presence of an engineer task can provide an estimate of the synergistic combat effectiveness of the engineer task. This analysis done for all critical engineer tasks could provide common measures of combat effectiveness to compare the training levels of performance of different engineer tasks. Eventually, further analysis of tasks' training levels of performance may indicate that certain subtasks trained to particular levels of performance will provide a substantial change in engineer combat effectiveness.

The relationships of the variables of task "execution" and "effect" measures of performance in the model can be changed to reflect changes in training procedures and hardware developments. The data collected in the field and stored in the General Data Base can be used to validate and update the relationships used in the model.

The development of the STAR model provides a method to relate training measures of performance to combat measures of effectiveness. The future ability to accomplish this across the combined arms spectrum will make the STAR model an important element in the proposed training system.

The arc from the STAR model to TRADOC in Figure 14 represents an information channel from the STAR model to TRADOC headquarters and the proponent schools. This arc closes the proposed training system loop. With the analysis provided from the STAR model, TRADOC will be able to set task training standards based on estimates of combat

effectiveness and provide guidance to the field units concerning the relative combat effectiveness of the critical tasks. Using the data collected and stored in the General Data Base, TRADOC will be able to monitor the overall progress of field units towards the training standards and update training guidance based on the units' progress. The National Training Center could be utilized by TRADOC to field test and analyze specific tasks' execution and effect measures of performance. In addition, both the STAR model and the National Training Center could be used to analyze the combat effectiveness of training and hardware developments.

Using the analysis provided by the STAR model and the other elements of the proposed training system, TRADOC will be able to manage the training system to maximize the combined arms' ability to win the land battle.

V. CONCLUSIONS AND RECOMMENDATIONS

The conclusions which may be drawn from this research and recommendations are presented in this chapter.

The conclusions are as follows:

- The individual and collective training systems discussed in Chapter II must be merged into one training system.

- The engineer task and mission network representations and the CPMTC analysis technique presented in Chapter III can be useful to many of the elements in the present engineer ARTEP system. Also, they are important to all engineer elements of the proposed training system presented in Chapter IV.

- TRADOC needs to receive ARTEP evaluation results to properly manage Army training. A feedback system to provide the results should be established and its use enforced.

- Methods and techniques must be established to estimate the relationship of training performance to training combat effectiveness.

- The USAES must determine the "effect" variables and the procedures to measure them for each of the ARTEP critical engineer tasks.

Recommendations are discussed in the following paragraphs.

Each proponent school should establish a study team to insure all the tasks and performance requirements in the soldier's manuals correspond to the ARTEP tasks and performance requirements.

The engineer task and network representations and the CPMTC technique should be emphasized in engineer units' ARTEP and also at all engineer NCO and Officer courses taught at the USAES.

Standard ARTEP evaluation forms should be established for each type unit and each unit's external ARTEP evaluation should be considered unfinished until the results are forwarded to the responsible TRADOC element. The engineer evaluation forms should be in a format which will facilitate recording the data concerning task "execution" and "effect" measures of performance discussed in Chapters III and IV.

A General Data Base should be established by TRADOC to store the information from training data sources. This data base would give all elements of TRADOC easy access to all combined arms training data.

The STAR model should be used by TRADOC to provide estimates of combined arms combat effectiveness for both training and hardware measures of performance.

The USAES should commit the necessary resources to determine engineer tasks' "effects" variables and the procedures to measure them. The "effect" and "execution" measures of performance should be modeled in the STAR model and recorded during ARTEP external evaluations and National Training Center exercises. These measures will provide the USAES with the information on tasks' combined arms combat effectiveness necessary to direct current training and plan future training and hardware developments.

The proposed training system presented in this thesis should be seriously considered by TRADOC as a necessary extension of the present ARTEP system.

This thesis represents only the first set of blueprints for the construction of the transition from training performance to combined arms effectiveness. The next step involves the collection of data concerning particular engineer tasks and actually representing the tasks in the STAR model.

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